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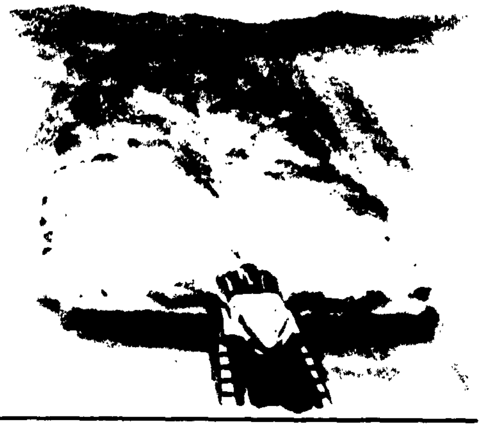
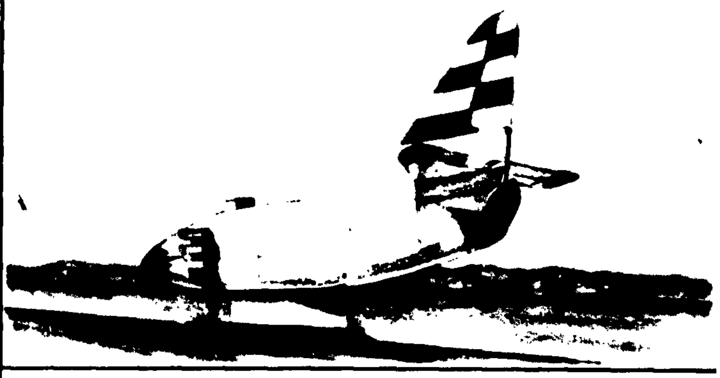
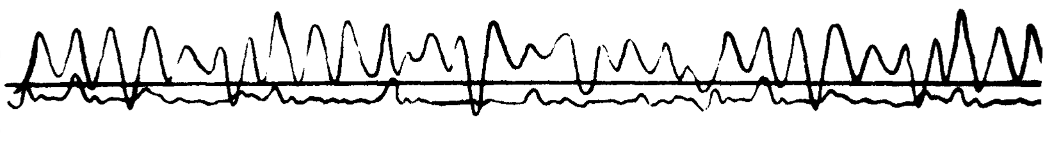


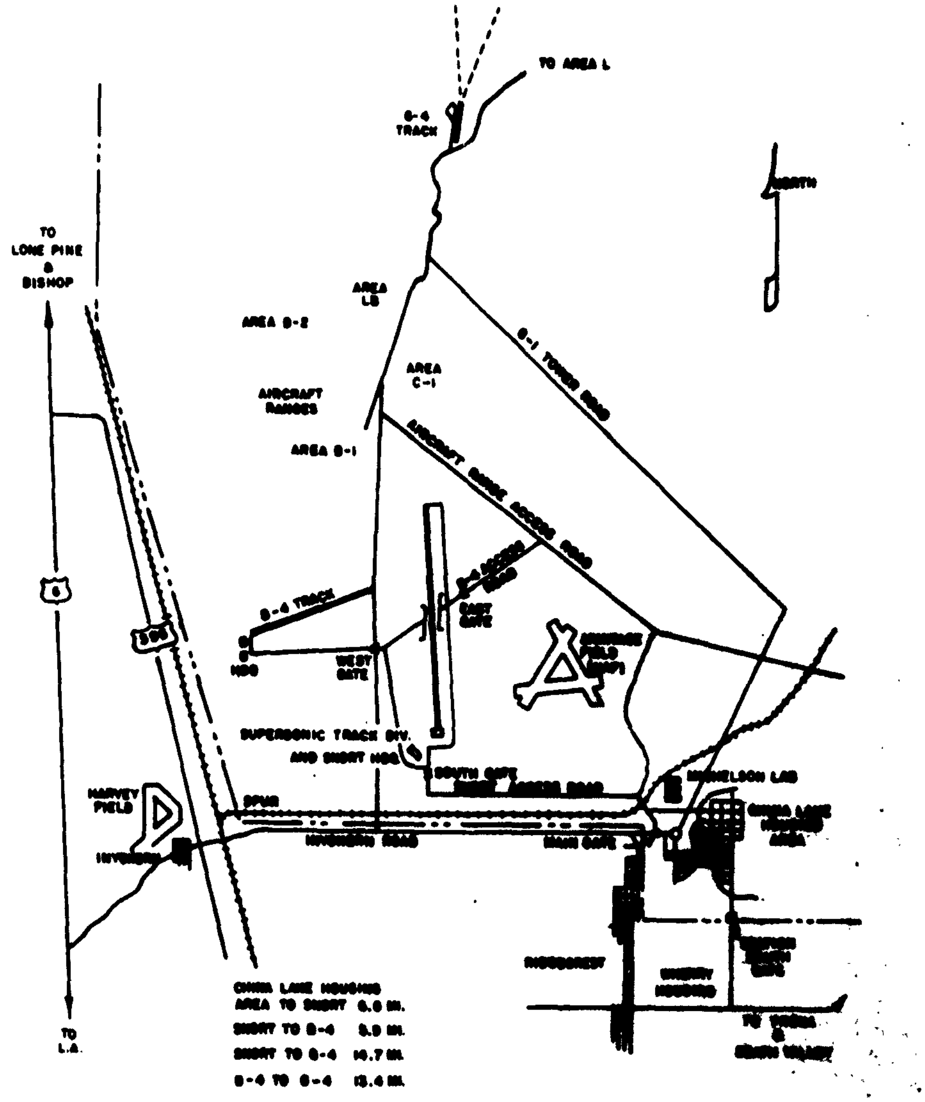
NOTS SUPERSONIC TRACKS



U. S. NAVAL ORDNANCE TEST STATION, CHINA LAKE, CALIFORNIA

NOTS 1938, REV. 1
SEPTEMBER 1962





Supersonic Track Range Access Map.

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

C. BLENMAN, JR., CAPT., USN — *Commander*

WM. B. MCLEAN, PH.D. — *Technical Director*

This report, published by Test Department, is the approved version of 30/MS/531; it is a revision of NOTS Report No. 1938 published in July 1958. Original printing, 500 copies.

FIG. 35. IBM 7090 Data Processing Facility.

DATA PROCESSING

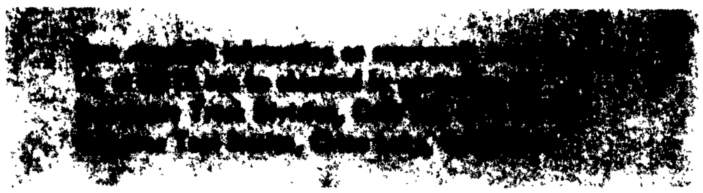
The Station furnishes all film-processing and photo-data-assessment services for track tests. Photographic film (both black-and-white and color) can normally be viewed the day following the test. Motion picture film prints can be provided within two to three days; color transparencies are usually available within four days. The time required for assessment of photographic records depends on the nature of the test, number of records involved, and complexity of the data reduction requirements.

Most electronic data records are processed and assessed at the Station. All telemetered data are recorded on 12-in. oscillographic paper and on magnetic tape. Paper can be processed in one day for delivery to the contractor; tape can be delivered immediately, or in the case of PDM and some FM/FM data, can be digitized directly for processing through the Station's IBM 7090 computer (Fig. 35). Track-coil data, recorded on magnetic tape and on film, can also be digitized for IBM processing; processing requires about two days. Direct-wire data are usually recorded on 7-in. oscillographic paper which is processed in one day.

TEST SCHEDULING

Meetings are held once each week at SNORT to schedule tests for the following week and to set tentative long-term schedules. In order to evaluate a proposed program in terms of data requirements and track resources, it is desirable that the project representative make an introductory visit to this installation early in the planning stages to obtain information on facilities and procedures before preparing a formal request. These preliminary negotiations are then followed by a written request which outlines the work to be done. This request should be made well in advance of the desired firing date and should cover the following points:

1. Purpose and scope of the test program.
2. Time scale required.
3. Relationship of the program at NOTS to the overall parent project.
4. Primary and secondary data requirements and accuracies desired.
5. Rate of testing and number of tests desired (i.e., the number of track runs, number of rounds to be fired, etc.).
6. Brief explanation of operating and physical characteristics of the device to be tested, including drawings or sketches, calculations of trajectory, drag, etc., and weight, size, and shape.
7. Statement of what the requester will furnish and what the Station is requested to furnish for the program.



FOREWORD

In the few years that high-speed test tracks have been in operation they have demonstrated their usefulness as vital laboratories in the expansion of knowledge in many scientific fields.

This report is written as a reference for use by NOTS personnel and others who need information on track capabilities, testing services, facilities, and equipment at the NOTS supersonic tracks. It includes a description of the tracks, sled structures, propulsion techniques, and instrumentation adaptable to test programs which require close-in photographic and electronic instrumentation data in a captive-flight environment closely approximating free-flight conditions.

The report was written during the period January through May 1962 and was financed by Station overhead funds.

Released under
the authority of:
IVAR E. HIGHBERG
Head, Test Department

LESTER G. GARMAN, Head
Supersonic Track Division

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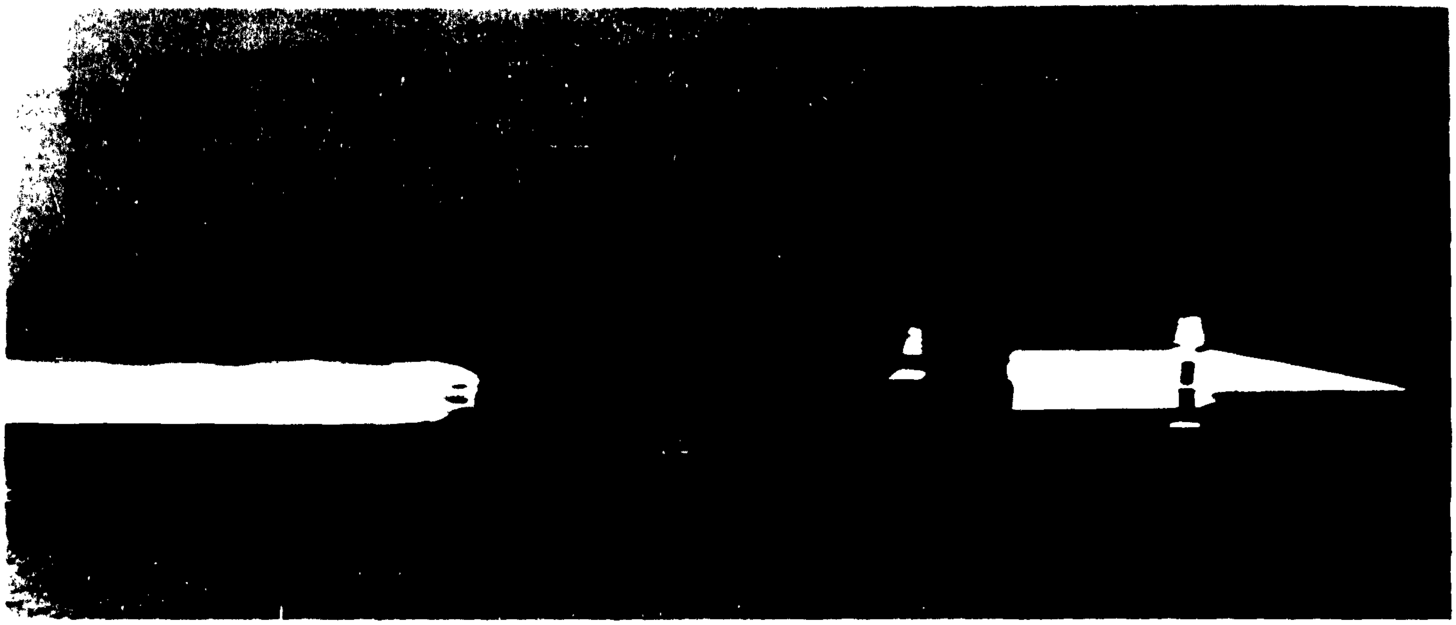


FIG. 1. Liquid Engine Test Vehicle Used in Testing Inertial Guidance Systems.

INTRODUCTION

Track testing has proved to be a practical and effective instrument in providing valuable information on existing and proposed weapons systems and their components. It combines many of the advantages of laboratory testing with those of free-flight testing and adds the important supplementary ability of recovery of test items for physical examination and retesting.

The NOTS supersonic track complex is a complete track testing facility consisting of three separate tracks—SNORT, B-4, and G-4—each with diverse, specific capabilities. Their geographical locations on the Station are shown in the frontispiece. The tracks are operated by the Supersonic Track Division which is comprised of three branches: the Project Engineering Branch, the Operations Branch, and the Instrumentation Branch. Permanently assigned personnel number about 60. In addition, the tracks are integrated with other Station facilities offering such supporting services as engineering design, project engineering and coordination, operational engineering, and data reduction and assessment.

This test facility offers a wide variety of sled structures and propulsion techniques in addition to a broad range of sledborne and close-in photographic and electronic instrumentation. With its access to other Station services, the Division is capable of performing complete track test programs from carriage design through static and dynamic (Fig. 1) tests, acquisition and assessment of data.

The three tracks are equipped to handle a great many different types of tests requiring simulated flight conditions, and to furnish data in the areas of aerodynamics, vibration, acceleration, velocity, pressure, and temperature. Following are some of the major specific applications of track testing:

captive tests

Rockets, guided missiles, model or full-scale aircraft, or their components are tested under conditions approximating free flight at velocities ranging from the subsonic through the supersonic. Data obtained includes measurements of thrust, acceleration, velocity, lift, drag, vibration, shock-wave effects, flutter, and aerodynamic heating.

aeroballistic tests

Projectiles, rockets, or missiles are fired or launched under simulated flight conditions to obtain information on expected performance in actual flight.

standard and VT fuze tests

Fuze functions are tested with recovery of test item, except on fuze impact tests.

inertial guidance systems tests

Inertial guidance platforms are tested under controlled flight conditions to aid in guidance package development and to check inertial system performance.

aircraft damage tests

Damage is created by impacting test items at high velocities against stationary targets and artificial weather conditions, or by gunfire. Aircraft damage tests are also conducted to determine effects of impulse loading under simulated flight conditions.

crosswind firing tests

Purpose of these tests is to determine ballistic trajectories and aeroballistic characteristics of small arms and rockets under crosswind firing conditions.

projectile recovery tests

Tests involving soft recovery of large gun projectiles are run to determine effects of gun firing on the projectile.

terminal ballistics tests

This type of testing shows damage potential of various missile warheads, and ascertains proper functioning of the warheads.

TRACK DESCRIPTIONS

The three tracks differ essentially in their length, weight capability, precision of alignment, degree of instrumentation, method of sled braking, and muzzle clearance. The following table lists their structural characteristics and typical uses:

track specifications

Item	SNORT	B-4		G-4
		Total,	3rd rail	
Length of track (ft)	21,500	14,560	11,000	3,000
Gage (inches)	56.6	56.6	13	33-7/8
Rail length (ft)	50	Varied		Varied
Size (lb/yd)	171	75		171
Continuous weld	No	Yes		Yes
Brake type	Water	Sand		Retro rockets if necessary
Brake description and length	See page 6	See page 8		See page 9
Artificial rain	Yes	No		No
Typical use	High-speed, heavy duty	Medium speeds, medium duty		External ballistics, and crosswind

Peripheral facility characteristics include:

1. Availability of IBM-7090 computer ballistic and performance programs for all tracks.
2. Standard slippers are used on all tracks—but are not necessarily interchangeable.
3. Track elevations are in the 2,000- to 3,000-ft above-sea-level range.
4. Ambient temperatures at track sites range from 20 to 80°F in winter and from 60 to 115°F in summer.

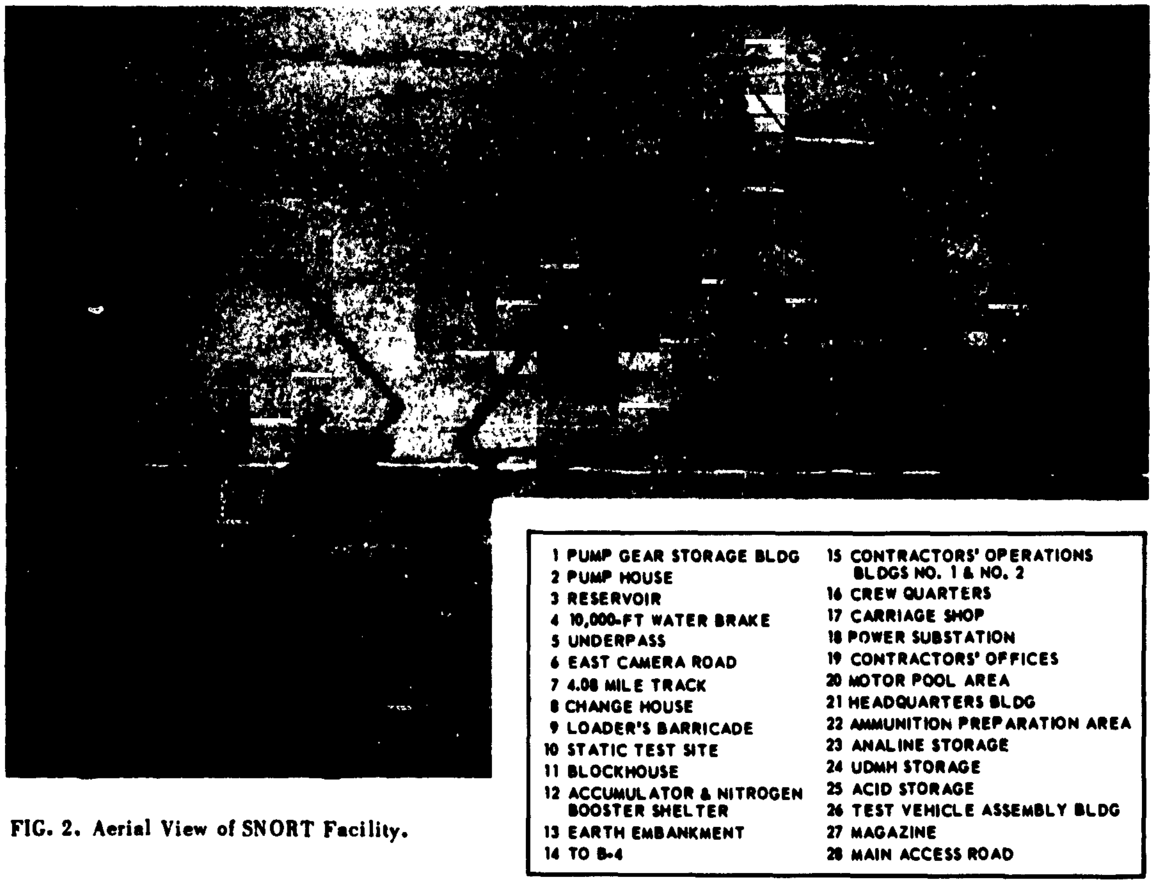


FIG. 2. Aerial View of SNORT Facility.

SNORT, shown in aerial view in Fig. 2, is a two-rail, heavy-duty, precision track approximately 4 miles long. Its profile (Fig. 3) consists of three vertical curves dipping a total of 107 ft in elevation from breech to muzzle; heading is N3°02'35"W. The track is made up of 50-ft lengths of 171 lb/yd crane rail laid at a 56.6-in. gage and mounted on adjustable sleepers attached to an H-shaped continuous concrete beam which is half buried in compact earth. The size of the trough formed by the upper half of the H configuration is constant for the length of the track; rail joints are butt-milled and doweled to retain rail-end alignment. Each 50-ft length of rail is supported on 13 sleepers—one located at each end and the other 11 spaced evenly at 4-ft, 2-in. intervals.

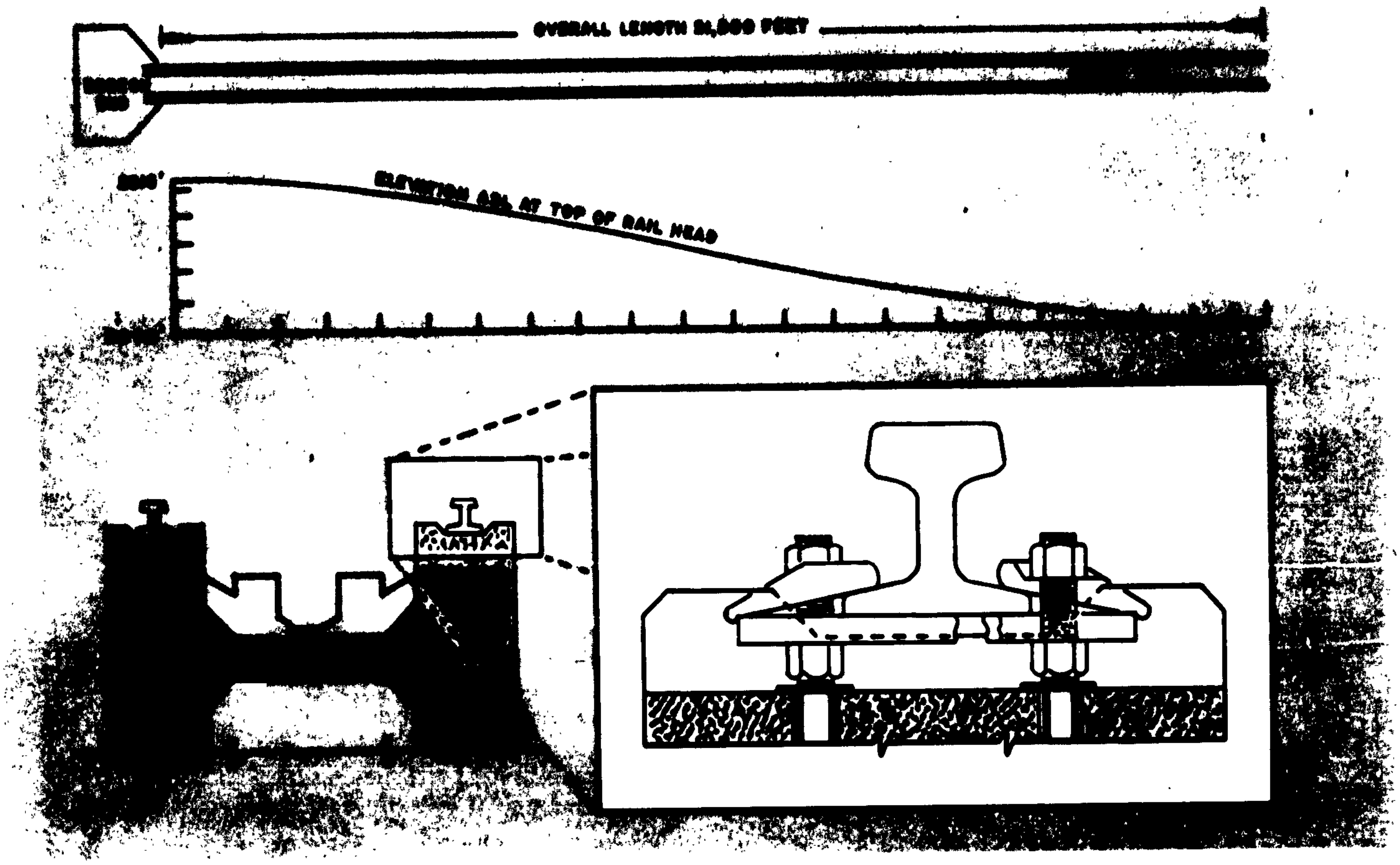


FIG. 3. Track Layout (SNORT).

Adjustment of the sleepers permits rail alignment to be maintained vertically to within ± 0.036 in. of the theoretical track profile at any point, horizontally to within ± 0.06 in. of the theoretical centerline, and to $\pm 1/2$ degree in rotation. The rail groove in the top of the beam is filled with asphalt between the sleepers to bond the rail to the beam and to dampen rail vibration.

The recirculating water brake system covering the last two miles at the north end of the track, consists of a well, a well pump, a reservoir, and a circulating pump. This circulating pump forces the water up hill and turns it into the trough between the rails. The water then flows back to the reservoir under the force of gravity to create a constant stream at a gradually increasing depth. Inlets are located at 11,525, 14,500, 17,000, and 19,000 ft downrange. Water can also be introduced at the south or breech end of the track, thereby extending the braking system to include the entire four miles. The water entering at the breech comes from a separate supply source and empties into the reservoir but does not recirculate. The breech inlet can supply water up to 1,000 gpm while the recirculating system can supply a maximum 1,400 gpm. Water depth in the trough is controlled by (1) the point of entry into the water brake trough, (2) the rate of water delivery at the entry point, and (3) the use of partial damming strips to retard the flow in the trough, or of frangible weirs to form a series of pools of varying depths. The profile of the water level is usually controlled by using a particular inlet plus partial damming; the flow rate may be varied for fine adjustment. Insertion of a scoop underneath the sled into water of graduated depth controls deceleration.

SNORT, being the longest, heaviest, and most precisely aligned of the tracks, is used primarily for tests requiring maximum speed or duration of run, heavy carriages, minimum of transverse or vertical vibration at high speeds, extensive or complex instrumentation, or controlled deceleration. Figure 4 shows a special test in progress.

FIG. 4. 155-mm Projectile Approaching Sled in Soft Recovery Test.

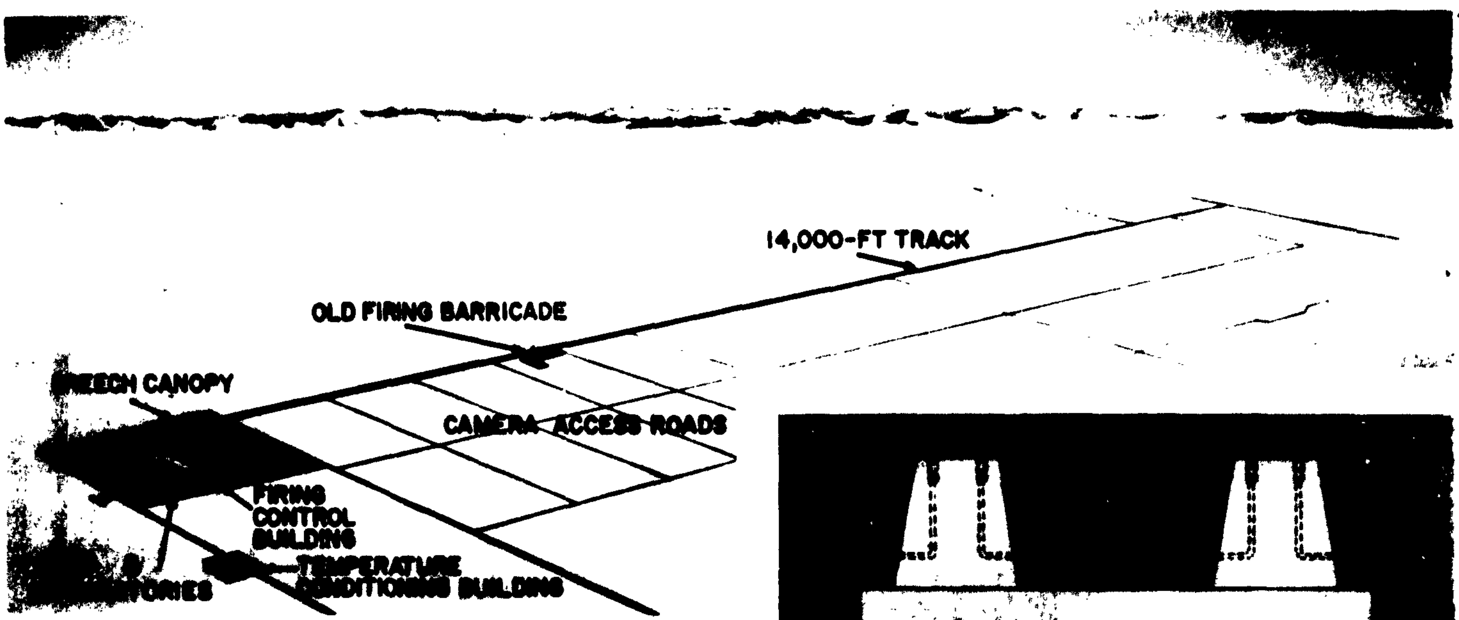


FIG. 5. Aerial View of B-4 Facility.

B-4 range

B-4, shorter than SNORT, is used primarily for standard missile component tests. Because of its less precise alignment and the fact that it can be repaired more easily, it is also used for tests that are more likely to result in damage to the track. Figure 5 is an aerial view of this 14,560-ft track which is laid over essentially level ground.

B-4 uses ASCE 75 lb/yd rail laid at a gage of 56.6 in. for the entire track length, plus a third 13-in. gage inner rail which starts 4,000 ft from the breech and extends downtrack to 11,000 ft. Track heading is N72°3′45″E. Three types of track support are utilized:

1. Reinforced concrete piers with vertically adjustable sleepers support 4,500 ft of track.
2. Concrete anchors and vertically adjustable cross-rail support, plus ties and ballast, are used for 4,000 ft of track.
3. Conventional tie-and-ballast railroad construction forms the mainstay for the remaining 6,060 ft of track.

Track support types 1 and 2, above, are shown in Fig. 6.

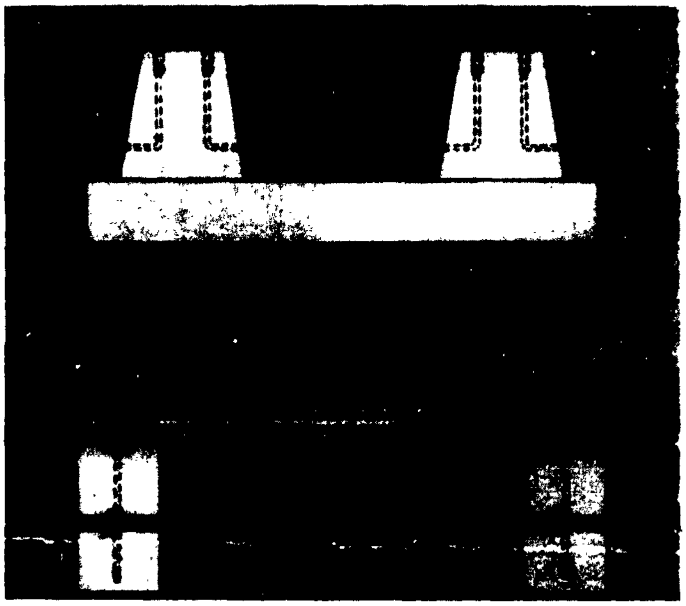


FIG. 6. Cross Section of B-4, Showing Two Types of Track Support. (a) Vertically adjustable sleepers; (b) Vertically adjustable crossties.

All rail joints for the first 13,000 ft are welded, thus splice bars have been eliminated. Alignment for the first 4,500 ft is held both vertically and horizontally to within ±1/6 in. of the theoretical track profile and centerline, ordinary railroad alignment is used for the rest of the track.

Deceleration is accomplished by a sand brake which is a probe extending beneath the sled to drag through loose sand between the rails. The braking area can begin at 6,000 ft, or at any distance beyond 6,000 ft, and extend to the end of the track. For this type of sled braking, sand is dumped into the space between the rails and then windrowed by a power-driven track car with underslung scraper blades. Sand depth is not varied since deceleration requirements for sleds used on the B-4 track are not stringent.

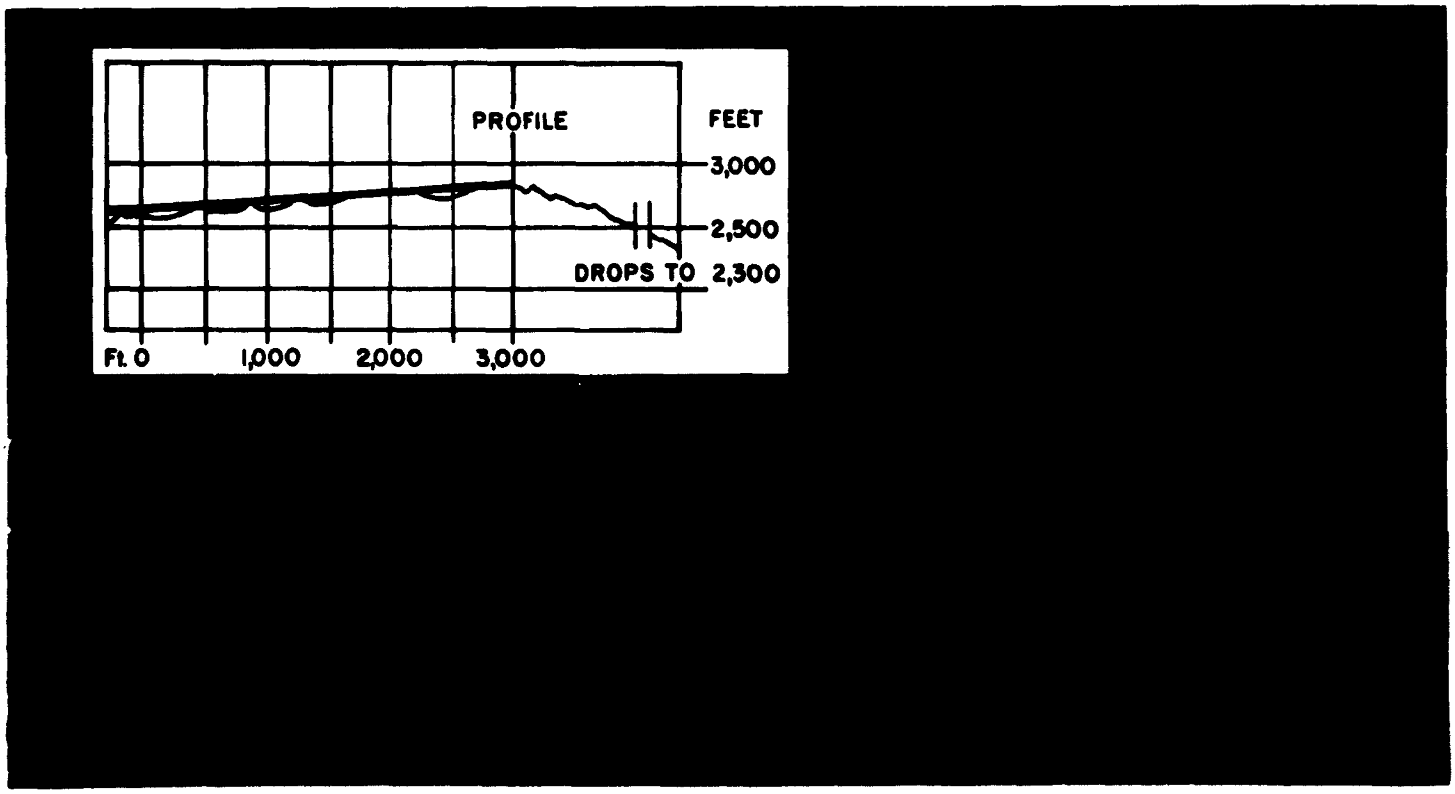
G-4 facility

This facility differs from the other two in that it is essentially a terminal ballistics track and is seldom used to obtain straight track-run data as such. The muzzle end of the track overlooks a desert sink 500 ft deep, which permits unencumbered free-flight exterior and terminal ballistics testing. See aerial view of G-4 shown in Fig. 7.

G-4 is a two-rail precision installation, 3,000 ft long, and inclined at a constant grade of +2.8% with a heading of N9° 10′ 38″ E. The track consists of 171 lb/yd crane rail laid at a 33 7/8 in. gage on adjustable sleepers attached to a U-shaped, continuous concrete beam. Rail joints are butt-welded and the U-beam is buried in a compacted select fill to within one foot of its top. Adjustment of the sleepers, which are located at 4-ft, 2-in. intervals, permits maintenance of horizontal and vertical rail alignment to an accuracy approximating that of SNORT and to within 1/6 degree in rotation. Rail vibration is damped as it is at SNORT by an asphalt rail-to-concrete bond.

For tests in which the sled is to be recovered, braking is accomplished by retro rockets; however, in most tests on this track the sled is expended. Velocities and accelerations achievable at G-4 are near those possible at SNORT within the 3,000-ft length limits.

FIG. 7. Aerial View of G-4 Complex.



CHECKOUT, MAINTENANCE, REPAIR, AND STORAGE

Assembly and shop facilities for the tracks are maintained at SNORT and B-4. SNORT has a three-bay test assembly building measuring 31 × 60 ft which is used for checkout, maintenance, repair, and storage of all liquid-engine sleds. Three buildings, located in the SNORT headquarters area, one measuring 40 × 62 and the others 40 × 80 ft, are used for assembly and checkout of test sleds and other items. There is also a contractors' headquarters building containing limited office space. In addition, standard storage facilities (consisting of one 25- × 40-ft magazine and three small magazettes) for storing solid propellants, fuzes, igniters, and high explosives, are located at SNORT. Other specialized types of storage facilities are available in other areas on the Station.

At B-4 there is a large machine shop servicing all three tracks in which four lathes, a large radial drill, three milling machines, two shapers, welding equipment, sheet metal equipment, and small pedestal drills are housed.

ROCKET TEMPERATURE CONDITIONING

A rocket temperature-conditioning building with units capable of maintaining temperatures from −80 to +200°F is located at B-4. Inside measurements of the units are 5 1/2 ft long by 3 ft wide by 7 1/2 ft deep.

ELECTRICAL SYSTEMS

Standards and specifications for proposed sled electrical systems are established by the Supersonic Track Division. Once the sled is at NOTS, the Division furnishes the source of sled power, performs static circuit checks, programs any special functions, and fires the sled. Two methods of firing are used: (1) initial ignition at the breech, and (2) downtrack ignition by means of knife-blade and screenbox. Firing or first motion of sled is not confined to breech and can be initiated at any point along the tracks.

Electrical Power, SNORT. The power source at SNORT has a 4,160-v primary from which are derived 208-v 3-phase and 120-v single-phase circuits for use at the breech of the track. In addition, the blockhouse provides 50-v d.c. to the breech. Th 208- and 120-v circuits extend downrange along the camera road (offset 1,100 ft from the track) for the length of the track, with outlets every 500 ft. Portable generators are on hand to provide 208-v 3-phase and 120-v single-phase a.c. power for instrumentation located at other sites.

B-4. Power at the B-4 range is supplie by a 4,800-v primary which delivers 208-v 3-phase and 120-v single-phase a.c. current to the breech and at 200 ft intervals along a line offset 500 ft to the south for the first 2,000 ft downtrack. Temporary lines are available to carry this voltage from the 2,000-ft point to the end of the track. The breech has three firing lines—one with 6- to 48-v d.c. power, and two with 115-v a.c. power. This same power is also available downrange.

G-4. G-4 is also supplied by a 4,800-v primary delivering 208-v 3-phase and 120-v single-phase a.c. power to the breech and at 200-ft intervals along a line offset 600 to the west for the full length of the track.

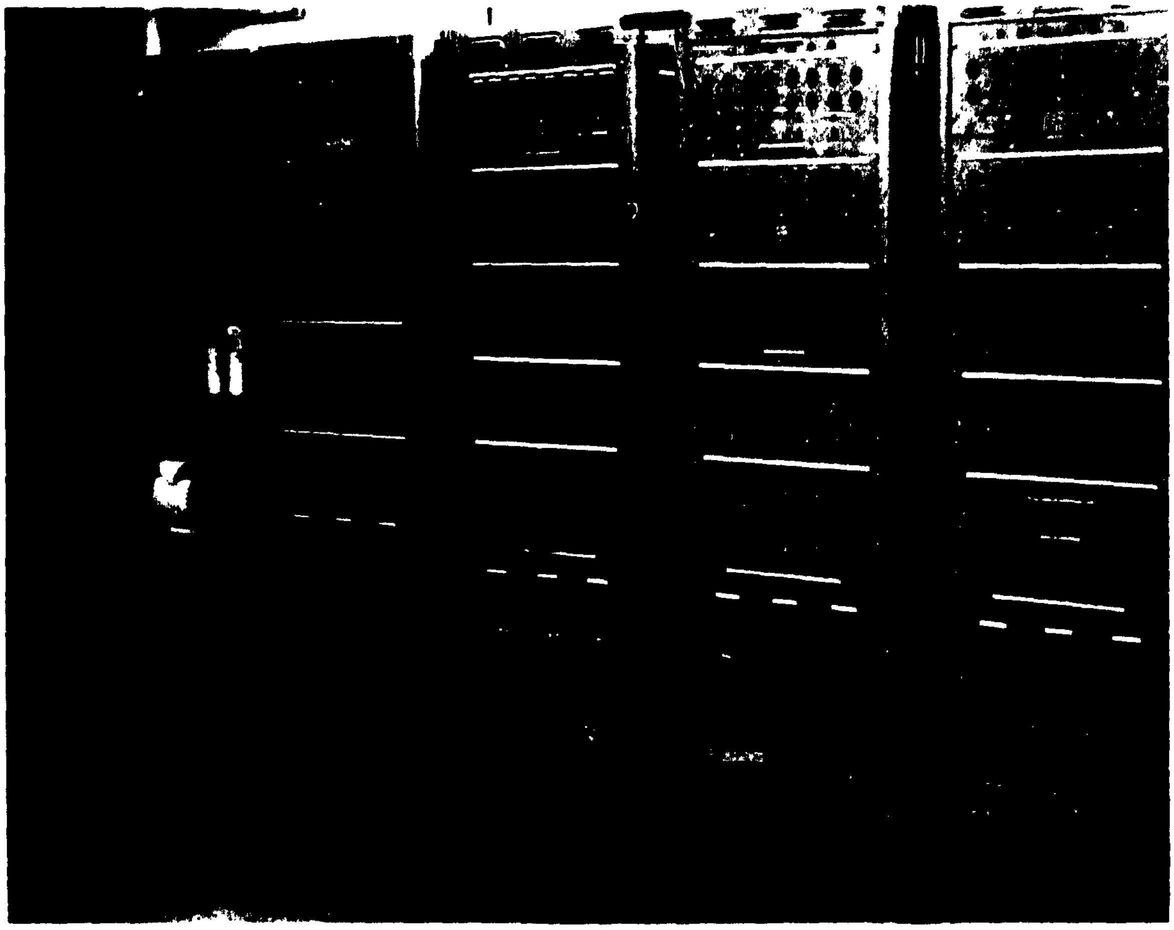


FIG. 8. SNORT Programming System.

TRACK PROGRAMMING SYSTEMS

SNORT Programming. The tracks are equipped with programming systems for control of firing and instrumentation. The SNORT programming system (Fig. 8) consists of equipment for control of events, with provision for sled-position control of events. Control lines extend from this equipment to racks and consoles in the firing-control building, the blockhouse, the breech, and downrange to numerous camera-control boxes. Functions of the SNORT programming system are:

1. To count increments of time from a selected preset time down to zero (firing time) and into a plus count if necessary.

2. To provide control signals for the starting and stopping of relay-controlled apparatus.

3. To control the firing of the test sled through a system of safety interlocks and automatic and manual hold-fire features.

B-4 and G-4 Programming. The B-4 and G-4 programmers are similar in function but less elaborate than the SNORT system. B-4 has a main firing-control programmer located in its firing blockhouse while the G-4 programmer is housed in a portable van supplied with power from generators or from Station power.

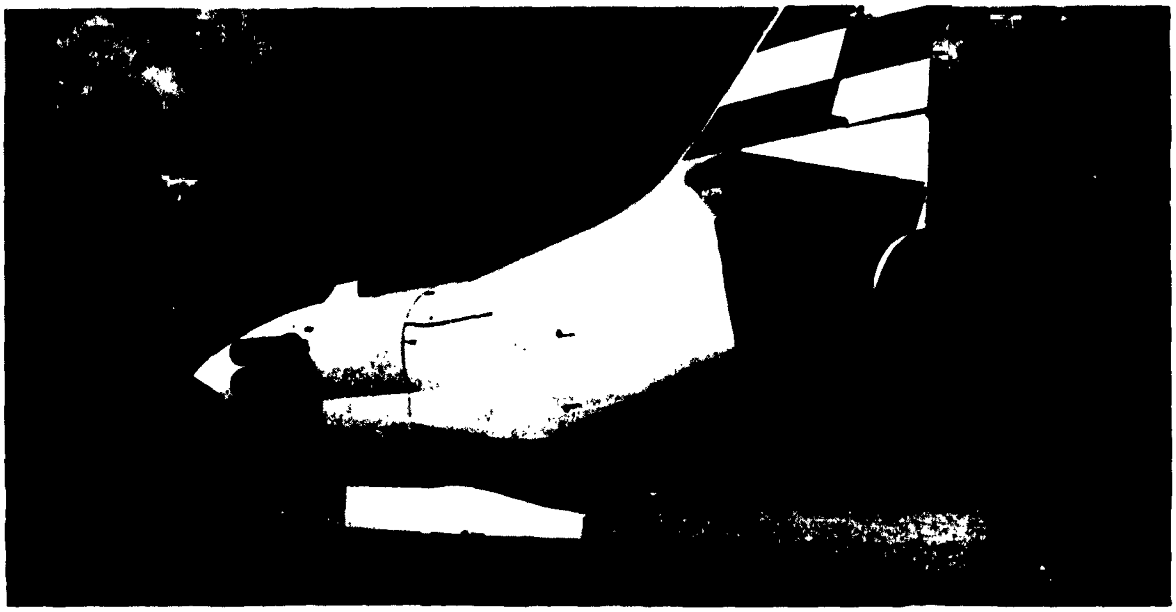


FIG. 9. A4D Aircraft Fuselage on Sled Ready for Flutter Test.

design and fabrication

The sleds that carry test items are as important as the track complex itself and are as diverse in type as the programs they support (see flutter test setup in Fig. 9).

Test sleds for specific programs are obtained by one of the following five methods:

1. The Division maintains a 'used-sled lot'. A sled built for a particular program can sometimes be reused in another program—either as-is or with modifications. Adaptation of a sled for a new test may range from the minor alterations necessary to permit attachment of the test item, to a major redesign of the structure to meet aerodynamic requirements. Sometimes a sled designed for SNORT can be used on B-4 (and vice versa) merely by changing the shoes and axles.

2. A sled may be designed by Track Division personnel and built in the track shops.

3. A sled may be designed by a central design facility of the Station, then be built at NOTS—either in the track division shop or in the main Station machine shop.

4. The Division may contract the design and fabrication of a new sled (or the modification of an existing one) to an outside firm.

5. The requester of the test may design and build his own sled. In this case, NOTS provides design guides such as the Supersonic Track Handbook, IDP No. 1055, and will, if desired, conduct feasibility studies to help determine the most applicable sled configuration, propulsion limits, aerodynamic loading, final weight limits, and other test vehicle parameters.

FIG. 10. Monorail Test Sled Configuration.

FIG. 11. Dual-Rail Test Sled Configuration Showing Combination of Various Solid-Propellant Motors Used for Controlled Impulse and Thrust.

sled configurations

The test sled consolidates payload, propulsion, instrumentation, and accessory equipment into one package. It may take many diversified forms from the highly-faired, aerodynamically clean type used to explore the transonic and supersonic speed ranges, to the relatively simple all-purpose utility type for testing in the subsonic and low transonic speed ranges. Sleds vary in size from the monorail type (Fig. 10) weighing a few hundred pounds, to the large, dual-rail type weighing many thousands of pounds (Fig. 11), and may be powered by either liquid or solid propellant rocket engines. However, all sleds are carried on slippers which grip the rail head to prevent derailing.

When practicable, test vehicles are designed for multiproject use. For example, a sled may be designed for use in several seat-ejection programs, or for use in a 100 or more tests of various guidance systems or missiles. However, most vehicles are built to accommodate a particular type of test since program requirements and physical dimensions of the load to be carried, normally vary widely. For instance, a test item which is usually an integral part of the sled may just go along for the ride; or it may require a special device such as a launching system; or it may need a special structure to withstand the snatch force of a deployed parachute; or it may call for impact which will destroy the sled. The cost of propelling a sled is an important economic consideration too, since propellant costs often exceed the cost of actual sled construction. Therefore, in many cases it is more costly to propel a sled too heavy for the function it is required to perform than it would be to construct a new and more suitable sled.

propulsion

Sleds are propelled by either solid- or liquid-propellant rocket motors; the propulsion to be used for specific tests being determined during sled design studies. Chief determining factors include desired performance, cost, and motor availability. Arrangements for procurement of motors are made jointly by the Station and the user.

Solid-Propellant Motors. Solid-propellant sleds at NOTS use JATOs and rocket motors of several types and sizes from the 10 NS 100,000 Nike booster down to the 3.0-in. LOKI, including the Tiny Tim, HPAG, and HVAR, 5KS 4500, 2.2 KS 11,000, and 1.8 KS 7800. By combining various combinations of these solid-propellant motors (Fig. 11), and by carefully programming their firing times (called staging ignition), a wide variation of impulse and thrust forces can be obtained.

Liquid-Propellant Motors. There are several types of liquid-propellant motors available from industrial sources. NOTS uses one of these, the Aerojet AJ10-103, in a sled maintained at SNORT. Overall sled-motor combination length is 22 ft; overall weight, when fueled, is 6,150 lbs. The engine can be used as a pusher motor, or, when fitted with its forebody, as a model tester. It can deliver 84,000 lbs of thrust from two 42,000-lb thrust chambers and has an inflight 2nd chamber ignition capability. The maximum burn times are 11.0 sec for a single chamber and 5.5 sec for both chambers. Thrust termination prior to fuel exhaustion can be effected by operating a knife switch mounted along the track which actuates a shutdown switch to release the nitrogen, thus stopping propellant flow.

sled shoes

Track sleds use metal slippers as the structural link between sled and rail. The shoes used on SNORT and G-4 (Figs. 12 and 13), and on B-4 (Fig. 14), are usually of the steel wrap-around kind, fitted with sleeve-type or strip inserts of materials such as SAE 1020 or stainless steel. Inserts of either type can be reused if wear on a previous run has not been too severe. Sleeve-to-rail clearance is in the order of 1/16-in./side/flange. On all three tracks the shoes are fastened to the sled

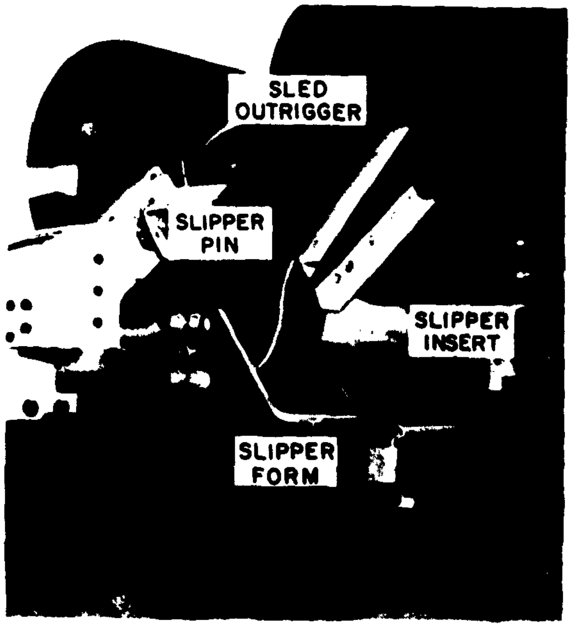
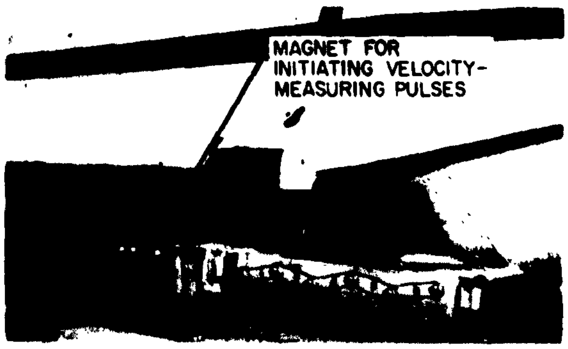


FIG. 12. Slipper Used on SNORT and G-4 Showing Form, Insert, and Pin.

FIG. 13. Double-Hung Slipper Installation With Magnet Mounting.



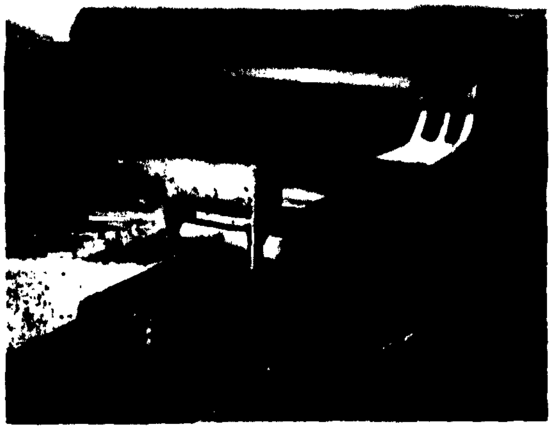


FIG. 14. Shoe Installation on B-4 Track.

frame by a single pin; at the end of the run, the sled can be slightly lifted, the pins removed, the sled hauled away, and the shoes dragged to the nearest end of the track for removal.

The Division maintains a stock of shoes for each of the supersonic tracks and usually furnishes shoes for a test sled. If stock shoes are not suitable or adaptable for the required run, the requester may be asked to furnish special shoes according to NOTS specifications.

brakes

Combined air drag and shoe friction are usually sufficient to stop a sled. At SNORT, when these forces are not sufficient, sleds are decelerated by either a probe type or horizontal-momentum-exchange water brake. The probe (Fig. 15) is a relatively simple and inexpensive attachment; the horizontal-momentum-exchange brake (Figs. 16 and 17) is more efficient than the probe, but it is also more complicated.

A stock of water brakes used on previous tests is maintained at the ranges; if these are not adaptable to a particular run, a new water brake is incorporated into the sled designed for that test.

At B-4 a sand braking system (which requires only a simple probe on the sled) is used, while braking at G-4, when required, is accomplished by retro rockets.

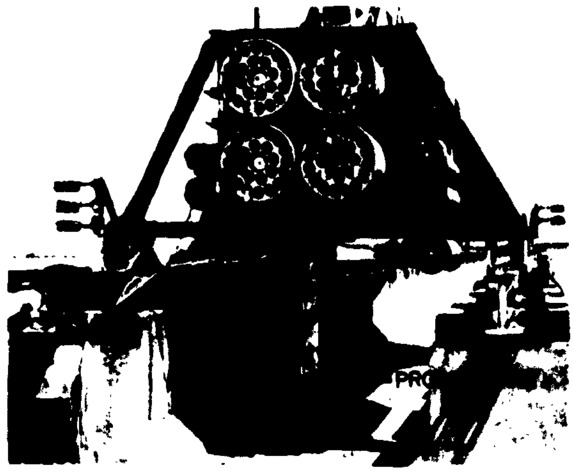
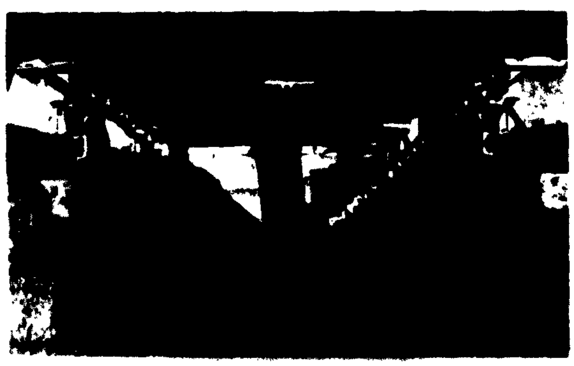


FIG. 15. Rocket Motors Mounted on Sled Using Probe Brake.

FIG. 16. Rear View of HME Water Brake, Showing Complete Structure Suspended Below Sled.

FIG. 17. Front View of HME Water Brake, With Outlet Sections Contained Within Sled Structure.



INSTRUMENTATION

Requirements for photographic and electronic instrumentation and measurement techniques vary to such an extent that individual instrumentation plans are established for each program. The following diversified equipment and techniques are used at the track ranges:

photographic instrumentation

The Station furnishes all photographic instrumentation required for track tests. Special cameras and photographic equipment are available to meet a wide variety of metric, visual-assessment, and documentary record requirements. Metric-photographic instruments, which can slow down and permanently record action in a form easily assessed and analyzed, lend themselves especially well to the gathering of data on dispersion, yaw, pitch, roll, trajectory, position-in-space, and in relating events to time. Some of the instruments used are CZR-1 ribbon frame, Mitchell, and Milliken cameras in addition to various types of Fastax and Photo-Sonics cameras. This equipment provides recording capabilities in all manner of combinations of half-frame 16mm to 5 1/2-in. wide film, picture rates from 8 to 16,000/sec, and with pin registration or rotary-prism continuous-film motion. Lenses with focal lengths of from 3.4 mm to 96 in. are used to obtain photographic records in either black-and-white or color.

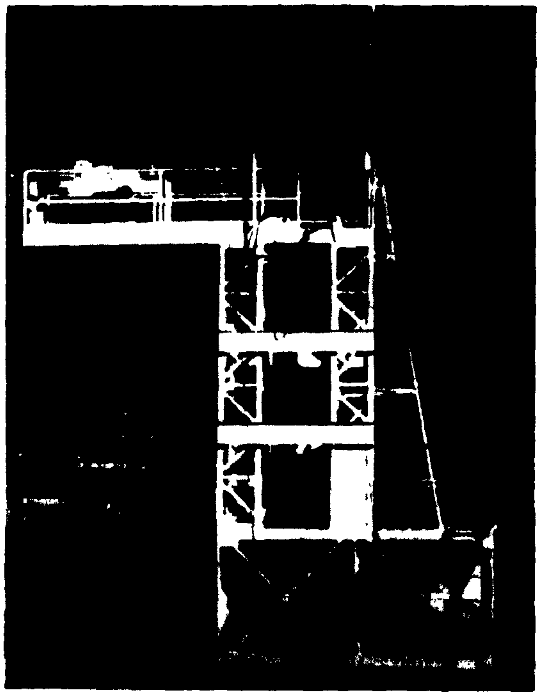


FIG. 18. Camera Boom for Overhead Coverage of Track Tests.

Most of the data requirements of a test can be met by positioning ground photographic instruments offtrack or on overhead mounts above the track (Fig. 18). However, some requirements can be met only by mounting a photographic instrument on the sled itself to record events occurring on or near the test vehicle during a run.

Ground Photographic Instrumentation. All photographic instruments used for ground-based recordings are equipped to record a standard time base directly on film so that the data can be time-correlated for assessment. High intensity light sources are sometimes used to supplement ambient light for very-high-picture-rate recordings.

Operation of ground instrumentation is usually controlled remotely on a time basis by a program sequencer, using landlines or a radio link. On tests where high velocity or the type of event makes sequencing of the instruments critical, control can be effected by sled position through the use of track-mounted switches which are actuated by the passage of the sled. Control can also be effected by utilizing an electronic time-position system that provides pulses as a sled proceeds downtrack. These pulses are counted electronically to a predetermined count which represents a certain distance downtrack.

FIG. 19. CZR-1 Ribbon Frame Camera.

Data on position, velocity, acceleration, attitude, and spin rates of ejected seats, dummies, and missiles can be obtained with ground-mounted CZR-1 cameras. Figure 19 shows a CZR-1 ready for action; Fig. 20 is a series of CZR-1 camera film frames taken during a seat-ejection test. These cameras have a continuously moving, wide film transport system housed within a rotating focal-plane shutter drum; they feature a frame 5 1/4 in. wide, varying in height from 0.15 to 0.9 in. depending on frame rate. Sampling rates are 30, 60, 90, or 180 fr/sec; exposure time can be as short as 1/25,000 sec. Each camera is supported by an independent three-axis mount which permits continuous rotation in azimuth, and rotation in excess of 180 degrees in elevation and roll. They do not track, but have a fixed field-of-view and are remotely controlled. Accuracy is sufficient to permit position determination in space of an object such as an ejected dummy, to within a few inches.

FIG. 20. Film Series Shot by CZR-1 Camera Showing Seat-Ejection Test.

Time, attitude, and dispersion data, as well as qualitative and documentary records, are obtained by 16mm and 35mm Mitchells and 16mm Milliken DBM-5Bs. The records from the medium speed (8 to 120 pictures/sec) Mitchells and the higher-picture rate (up to 500 pictures/sec) Millikens are used for timed-data measurements such as attitude, deflection, pitch, roll, and yaw. These cameras are pin-registered, have a large film capacity, and record timing signals and correlation pulses when required. Because of the excellent results they produce, these cameras are widely used trackside, on overhead mounts, and on tracking mounts.

Higher sampling rate requirements are met through the use of the Photo-Sonics 16 and 35mm, the Fastax 35mm, half-frame and full-frame 16mm, and other types of rotary prism cameras. These instruments offer picture rates ranging from 200 to 16,000 pictures/sec and are especially useful for slow motion studies of rocket launchings, impact tests, and warhead action. Large format coverage is obtained by the Photo-Sonics 10B camera which provides full- or half-frame 70mm coverage at picture rates of 180 or 360, and 720 per second, respectively.

Various photographic techniques used to record specific types of information unobtainable by standard practices include ballistic-synchro, streak camera, microflash, shadowgraph, and the use of high-intensity light sources. The ballistic-synchro technique, particularly adaptable to supersonic track data acquisition, is the only technique now available for obtaining large format, very-high-definition still photographs of very-high-velocity items (Figs. 21, 22, and

23). The image is recorded by a continuous-film-motion camera with the film moving in the same direction as the image. The moving image is scanned by a slit at the focal plane and is then recorded by the film.

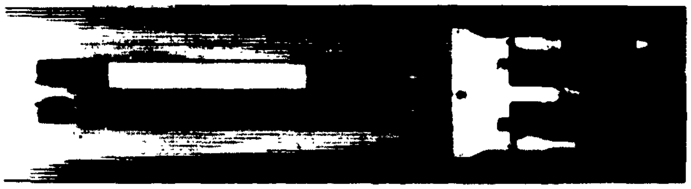


FIG. 21. Overhead Ballistic-Synchro Camera View of High Velocity Sled.

FIG. 22. Ballistic-Synchro Photograph of Forward Portion of Monorail Sled During High-Velocity Rain Erosion Test.

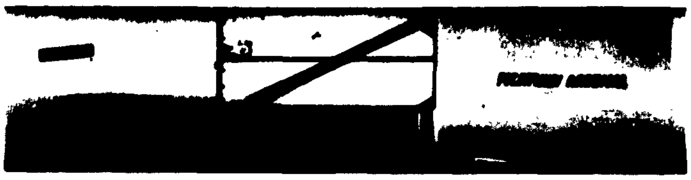


FIG. 23. 70mm Ballistic-Synchro Camera Photograph of 155mm Howitzer Shell Being Caught in Flight by High Velocity Sled.

The continuous-moving film streak camera is used to obtain position versus time information and in relating events to time. This camera can also be used in conjunction with microflash equipment to obtain short-exposure, stop-motion recordings. The shadow-

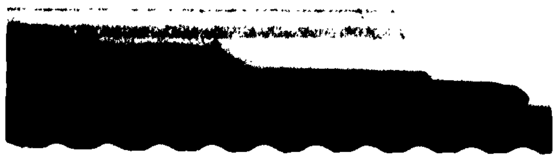


FIG. 24. Shadowgraph Photograph Showing Shock Waves.

FIG. 25. M-45 Tracking-Camera Mount With Mitchell Cameras.

graph technique is a method of obtaining shock-wave photographs of rapidly-moving sleds using a ballistic-synchro camera and a reflective light source (Fig. 24).

The M-45 tracking camera mount (Fig. 25) is a basic tracking unit using Mitchell, Photo-Sonics, or high-speed cameras with various lenses for tracking studies of high-speed test sleds and ejected items. These mounts are manually controlled and provide tracking rates up to 60 deg/sec. They are usually located on dirt mounds 3,000 ft offtrack, and can be spaced to cover an entire sled run.

Sledborne Photographic Instrumentation. Special sledborne photographic recorders, designed or modified to withstand the extreme physical environments experienced on test vehicles, are used to record action occurring on or near the sled during a test. This technique includes the use of Photo-

Sonics 1B cameras, providing black-and-white or color recordings at picture rates to 1,000 per second (Fig. 26), and Fastax cameras recording up to 4,000 pictures/sec for the 16mm full-frame format and up to 8,000 pictures/sec for the half-frame 16mm format. In addition, a pin-registered camera has been developed for sled use—one version has a 35mm half-frame format, the other a 16mm full-frame format, offering picture rates of 200 and 300 per sec, respectively.

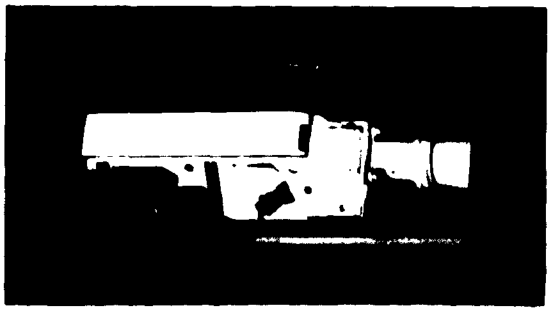


FIG. 26. Photo-Sonics 1B Camera in Protective Pod for Sledborne Use (Shown With Cover Removed).

Sledborne photographic equipment is controlled by sled-mounted squib switches which are actuated either by signals from the range programmer through a pullaway system or by sledborne knife blades making contact with charged screens mounted to the track. Two types of squib switches are generally used: one (an instantaneous type) starts the cameras; the other (a delay type) turns them off at the end of the sled run.

An independent time base for sledborne camera recording is provided by a sled-carried 100- or 1,000-cycle oscillator. The timing signals can be telemetered for comparison with the master range timing signals if necessary. Sled-position indication for time correlation can also be recorded by sledborne cameras using sled-mounted knife blades and track-mounted screen boxes, or by placing flash bulbs in the field-of-view of the cameras.

electronic instrumentation

Various electronic measurement techniques, which provide high accuracies and ease of data processing and computation, are used at NOTS. Electronic instrumentation and associated facilities at the track ranges are divided into three main categories: (1) telemetry systems and facilities, (2) timing systems, and (3) time-position systems.

Telemetry Systems and Facilities. The primary method of obtaining data from the test vehicle is radio telemetry; however, for some tests data is obtained through the use of sledborne direct record or landline systems. FM/FM telemetry is the most commonly utilized method, although in some instances PDM and PCM systems are used.

The SNORT telemetry receiving/recording station, located on the second deck of the headquarters building (Figs. 27 and 28), is

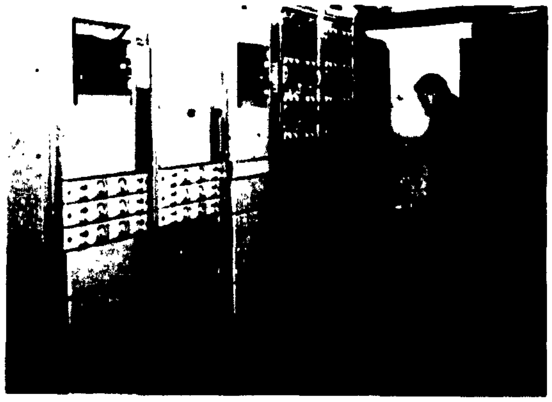


FIG. 27. North Section of Telemetering Receiving and Recording Station at SNORT.

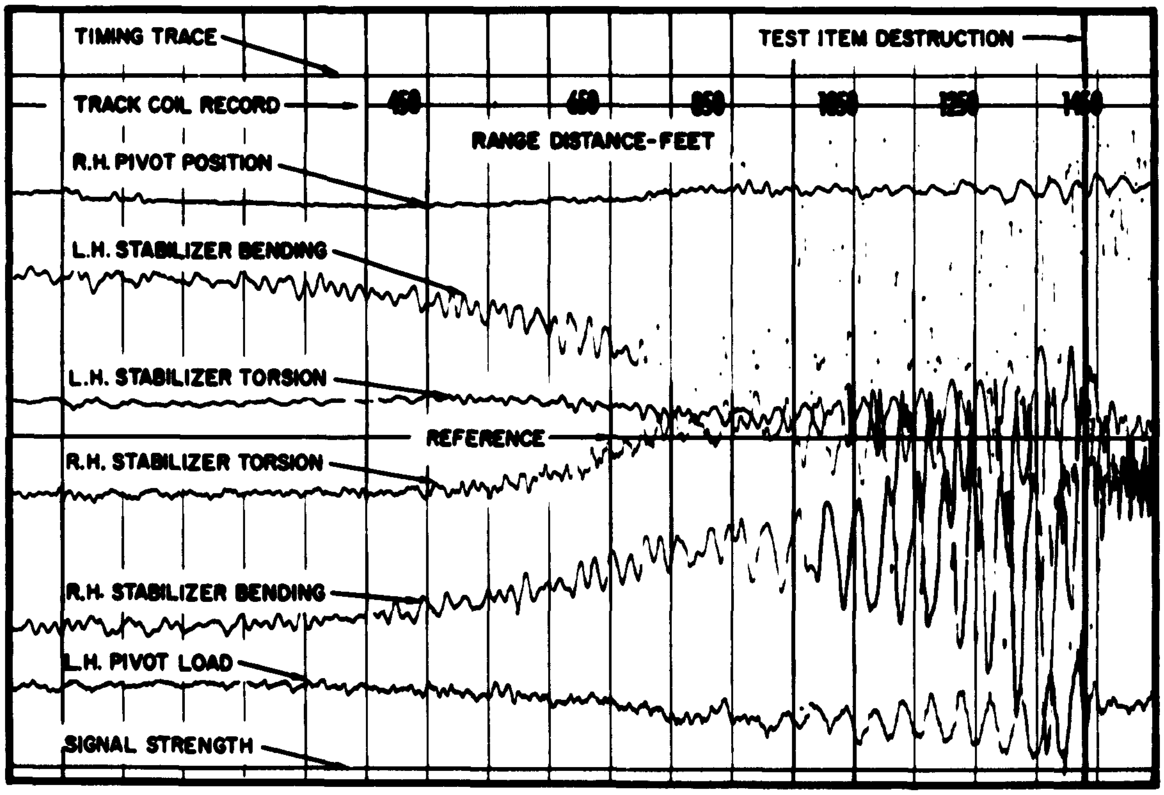
FIG. 28. South Section of SNORT Telemetering Ground Station.

the most complete; a mobile telemetry receiving/recording station is used at B-4, G-4, and downrange SNORT when necessary.

The SNORT station, capable of receiving seven FM/FM-PDM/FM telemetry carriers in the 200 Mc band, uses Nems-Clarke crystal-controlled phase-lock receivers. Two Ampex FR107A magnetic tape systems are provided for recording and playback of the telemetry composite signals. Each system provides six channels for composite signal recording and one channel for multiplexed recording of the 17 kc speed-lock signal, time-position information, 10-bit coded timing, 50 kc time base, voice annotation, 100 BCT timing, and five RF signal strengths. Two complete FM/FM discriminator systems with tape speed compensation are provided, each with a CEC 36-channel oscillograph for real-time and playback records (Fig. 29). Datarite magazines are provided for quick-look records, and a complete selection of Gaussian low-pass filters is available. Checkout facilities in the telemetry station include a panadapter, 11-point discriminator calibrator, and a subcarrier indicator for deviation checks. Facilities are also available for receiving and analog-recording of digital information carried by one RF channel. Pulse-duration modulated (PDM/FM or PDM/FM/FM) and pulse-amplitude modulated (PAM/FM/FM) telemetering signals are received and recorded as unseparated data; no decommutation equipment is presently available.

The mobile telemetry ground station provides complete facilities for receiving up to four telemetry RF carriers. The sta-

FIG. 29. Typical FM/FM Telemetry Record of a Flutter Test.



tion is also equipped with crystal-controlled phase-lock receivers, has a total of 12 EMR Type 67 discriminators, an FR100 Ampex tape recorder, and a CEC 36-channel oscillograph plus a Datarite Magazine. Facilities for checkout include a panadapter, 3-point calibrator, and a subcarrier analyzer. Communication and timing equipment is also provided. This station is intended to be used only for real-time records and for tape data recordings. Playbacks, when required, are made at the SNORT station which has speed lock and tape-speed compensation capabilities.

A PDM/FM telemetry receiving station is installed at the B-4 blockhouse and consists of a Nems-Clarke crystal-controlled 1400 series receiver, and an Ampex FR100 tape recorder. This system provides up to six channels of PDM or analog recording and one channel of direct record for time-position information, speed-lock control signal, and voice annotation. Data tapes are played back at the SNORT telemetry station. Monitoring facilities are not available at the B-4 station.

Sledborne electronic instrumentation systems are designed for specific track test programs and are sometimes furnished by the track customer due to special requirements, expediency, or availability of special equipment. Other systems (fabricated in-house, by other Station groups, or under commercial contract) are furnished by the track ranges. Standard or 'universal' FM/FM packages, complete with power supplies, control and calibration circuitry, and usable with various types of transducers, have been designed for easy adaption to test requirements.

Wire-connected telemetry equipment is used to transmit data on phenomena (i.e., temperature, voltage, power, and position) occurring on the test sled before firing; those, such as accelerations and transient loads, occurring during the first few feet of travel; and for special data on events occurring during the initial portion of the run. Trailing wires permit data to be recorded for distances up to a few hundred feet. These systems are also used in some tests to record data such as the impact of a sled-mounted target with a test item suspended over the track. Since the wire-connected method of obtaining data is applicable to a relatively few track tests, each with varied requirements, no standard systems have been established.

The test and calibration facility at the SNORT headquarters building is capable of handling major checkout and calibration requirements for telemeters, transducers, and direct record equipment. This facility includes a vibration table, a centrifuge, precision voltage calibrator, pressure calibrating system, electronic counters, and other equipment necessary to complete the facility. Portable checkout units are available for use at the assembly buildings and at field locations.

Timing Systems. Each track range uses an independent range-timing system, with permanently installed facilities at SNORT and B-4, and a mobile system for use at G-4. Precise timing-function data are derived by digital techniques at a central station and transmitted to instrumentation sites via a 9-channel pulse-coded-modulated (PCM) UHF radio link (4 channels at B-4 and at the mobile station). The timing functions consist of gate signals, elapsed-time counts, synchronization and control signals, and a binary-coded time base which is used to correlate all photographic, oscillographic, and magnetic tape data recordings. The various channels are used for controlling recording equipment at field locations and for transmitting the coded time signals. Other signals from d.c. to 10 kc can be transmitted if required for special

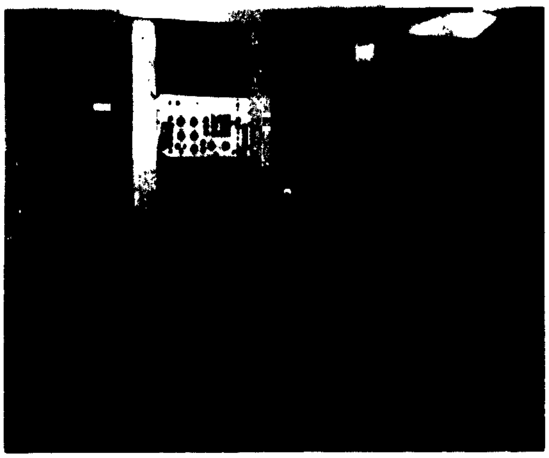


FIG. 30. PCM Central Timing System at SNORT.

control and correlation. The SNORT PCM central timing station is shown in Fig. 30.

Overall system accuracy depends upon the reliability of the secondary 100 kc frequency standards which are used as the primary time base. The timing pulses presented by these systems occur every 0.001 sec. At present the Division has 20 portable timing receiving stations (Fig. 31), each of which can provide timing signals to several field recorders if the recorders are located within a relatively small area.

Track overheads are equipped with permanently-installed timing receiving equipment.

FIG. 31. Portable PCM Timing and Receiving Station.

Time-Position Systems. The track-sled system which obtains time-position information for the computation of sled acceleration and velocity (Fig. 32) is essentially a two-dimensional, space-time continuum with the track as the space dimension and the sled existing along this dimension in time. Each track uses a progressive series of magnetic pickup coils located at predetermined intervals along the track to permit recording of test vehicle velocity/acceleration between coils. A magnet mounted on the sled energizes each pickup sequentially for the distance of the test run.

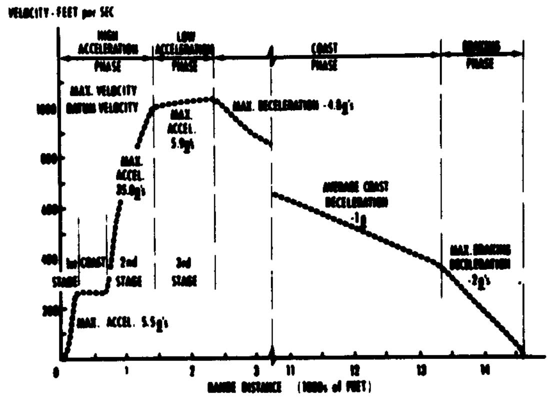


FIG. 32. Velocity-Distance Profile Computed From Track Coil Data.

At SNORT the pulses, transmitted by landlines to the terminal timing and recording equipment (Fig. 33), are recorded along with timing by an oscillograph, a 35mm streak camera, and a tape recorder. At B-4 an oscillograph and film recorder are used, and at G-4 the track-coil information is recorded by a mobile recording van. Pickup coils are mounted at SNORT every 100 ft for the entire length of track; at B-4, every 25 ft for the first 2,000 ft of track, and then every 100 ft to the 10,000-ft mark; and at G-4 every 50 ft for the first 2,600 ft then every 25 ft for the remaining 400 ft of track.

Systems to obtain a real-time plot of velocity versus distance (or time) are presently under development for installation at SNORT and at B-4.

FIG. 33. Terminal Equipment of SNORT Time-Position and Velocity Measuring Systems.

A more precise velocity data is obtained at SNORT by means of the velocity measuring system (VMS) which was developed for testing inertial guidance systems but which is used in other tests requiring this degree of accuracy. The VMS simultaneously records sled-position (determined by the track-coil system) and longitudinal accelerations of the sled (measured by a sledborne accelerometer and transmitted by a 1 × 900 PDM/FM telemeter. By combining these data in the IBM digital computer, all components of velocity between 0 and 50 cycles can be obtained to an accuracy of 0.1 ft/sec over a sled velocity range of 200 to 2,000 ft/sec. The velocity measuring system incorporates a precision pulse converter which provides a pulse accurately indicating the zero cross-over point of the track coil pulses. It detects the center node on the track coil pulse waveform and generates a square wave, the leading edge of which marks the exact time when the center of the sledborne magnet crossed over the center of the magnetic pickup. This equipment gives the average velocity or acceleration of the test vehicle between the magnetic pickup coils and provides a precision pulse for assessment of the track-coil record (Fig. 34).

Occasionally it is necessary to determine test vehicle velocity instantaneously at specific locations along the track. This information can be obtained to one-tenth microsec by using a break-circuit system actuated by the passage of the sled to control a chronograph or to provide an oscillographic record of the interruption of the circuits versus time. It is thus possible to obtain the time interval required for the sled to pass between two or more points and then to derive the sled velocity at a particular location.

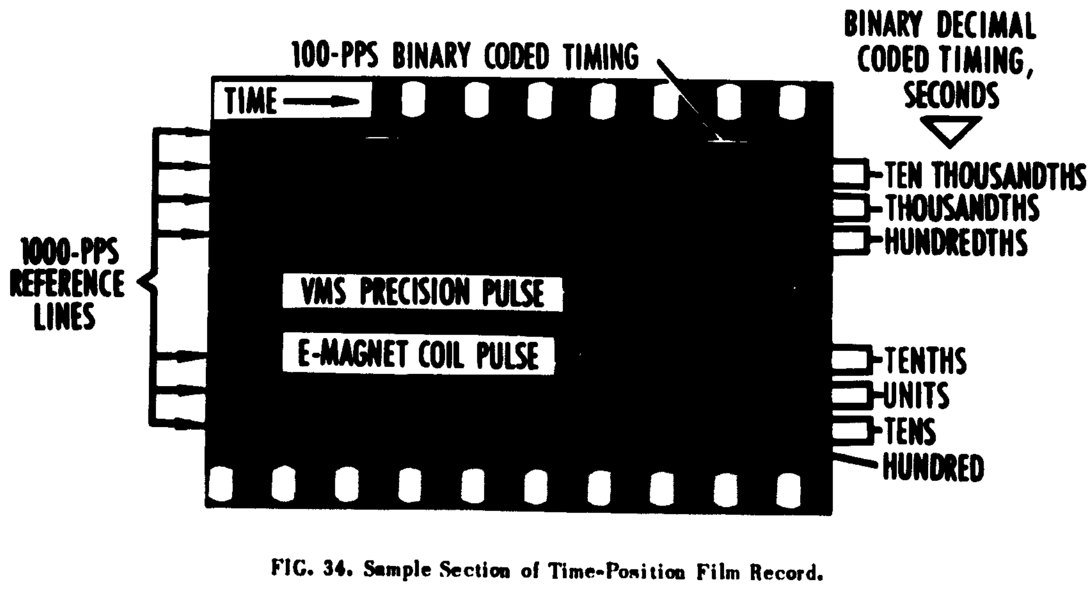


FIG. 34. Sample Section of Time-Position Film Record.

COMMUNICATIONS

Integrated communications systems involving radio networks, and intercommunication and public address systems are used for safety and for control and direction of test firing operations. In addition, all offices and work areas are equipped with telephones.

Radio communication systems consist of transmitter/receiver units mounted in automotive vehicles, and permanently installed radio repeater stations at both SNORT and B-4. Mobile units transmit selectively to either the SNORT or B-4 base station which, in turn, transmits on a different frequency and at much greater power.

An auxiliary radio communication system has been established at SNORT for communication between downrange instrumentation locations and the SNORT programmer. This system, involving portable handi-talkies, vehicle-mounted units, and a base station, is used by personnel establishing instrumentation systems and arrays at separated locations and for checkout of programmer control circuits; it is unrelated to and does not communicate with either the SNORT or B-4 primary radio systems.

Intercommunication and public address facilities are located at SNORT for communication between offices, assembly areas, fire control, instrumentation operating areas, blockhouse and track breech, and downrange locations. Intercom stations are installed at downrange SNORT for specific test operations and are connected to a permanently installed system which has stations at fire control, operating areas, breech, programmer, etc. All buildings, offices, operating areas, and the headquarters areas are covered by a public address system. The SNORT breech area is covered by bull horns mounted on the blast wall and driven by two 200-watt audio amplifiers located in the blockhouse. Intercommunications, public address, and radio communications systems are integrated and interconnected for complementary functions. In addition, SNORT also has an administrative intercom system which interconnects the various offices, buildings, and work areas.

The B-4 track has communications facilities similar to those at SNORT except on a smaller scale and with fewer stations. All major buildings, work areas, and offices are interconnected with each other and with the track breech. Downrange communications are usually handled by radio although intercom units (carrier-type) can be installed if required. A public address system is provided which covers the buildings, offices, work and operating areas, the track breech, and outside areas.

No communications facilities have been permanently installed at the G-4 track; however, a portable radio repeater station is installed in the area when radio communications are required. Portable carrier-type intercom units are set up as needed and a public address facility consists of a small system installed in the mobile firing van used at that range.

Telephones are installed (or can be installed on short notice) in all offices and work areas assigned to contractor personnel at SNORT and B-4. There is also a telephone located at the G-4 breech area which can be dialed directly from SNORT, B-4, or from the main part of the Station.

A closed-loop television system is located at SNORT for surveillance of the breech area during test preparation and firing operations. This system, located 135 ft east of the track breech, is remotely controlled from the test-control room in the headquarters building and consists of a television camera equipped with a Zoomar lens. Viewing monitors are located at the blockhouse and at test control.